ANATOMICAL GEOMETRY AND DENSITY DISTRIBUTION DATA BASE*

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ABSTRACT

Precise and detailed three-dimensional geometry of the human body and density distribution of various tissues and skeletal structures are essential in many aspects of research related to biomechanics. This paper describes a data base consisting of such quantities. The computerized tomographic technique is used to derive this data base. The experimental procedure is described first followed by a description of the structure of the data base and some of the information retrieval programs, concluding with suggestions for possible applications of the data base.

I. Introduction

In biomechanics related research, certain quantities of biological structures under study, for example, their three dimensional geometry and density distribution, must be known. However, when the biological entity under study is the human body, these quantities become difficult to obtain. With the recent advent in radiological computerized tomography (CT) [1,2], it is possible to obtain these quantities very precisely and systematically.

The purpose of this paper is to describe a data base containing quantities derived from the CT method. At the present time, the data base to be described includes only body geometry and mass density information of human cadavers scanned in a supine position. However, due to the relatively non-invasive nature of the procedure, it is our future plan to include information on cadavers scanned in various anatomical positions, as well as, information on live human subjects and live animals into the data base. For each cadaveric specimen, the following five types of information are being preserved:

(1) CT scan picture of each cross section
(2) Geometry of a body segment (or cross section)
(3) Mass density distribution of a body segment (or cross section)
(4) Geometry of internal organs
(5) Mass density distribution of internal organs

Since CT technology is well-known, the reader is referred to references [1] and [2], for details. In the following, we will only review the CT scan picture format [3], and then briefly describe the experimental procedure. This will be followed by a description of the anatomical cross-sectional geometry and the mass density properties data base.

II. Computerized Tomographic (CT) Scan Picture Format

Computerized tomography (CT), a recent advent in radiographic technology, was first used for medical purposes in 1974.[1,2] In CT, a scanner generates cross-sectional patient scans, which reveal significantly more diagnostic information than conventional X-rays, because they can differentiate soft tissues. The CT output consists of digital pictures of various sizes[3] (from 160 x 160 to 320 x 320 picture elements), each picture representing a cross-sectional anatomy with a thickness of from 7mm to 13mm. The value of each pixel (picture element) indicates the X-ray attenuation of a tissue area approximately 1.0mm x 1.0mm to 1.5mm x 1.5mm, but it also relates to tissue mass and electron density. At the present time, CT Scanners can differentiate tissues within .5% of X-ray absorption. Because of the excellent quality of instrumentation and its noninvasive nature, computerized tomography has opened up a whole new avenue in medical diagnosis, as well as applications.

III. Derivation of Anatomical Cross-Sectional Geometry and Density Distribution from CT Scans

The major steps in deriving anatomical cross-sectional geometry and mass density distribution from CT scans are as follows:[4]

1) <u>Acquiring and Preparing A Cadaver</u>

The first step is to acquire a suitable specimen. The basis for selecting a cadaver are age, height, weight, and condition of the subject's past health. Once a specimen is selected, it is kept at 40°F until the scanning begins. In order to recognize levels, erasable marks are put on the skin of the body.

2) Scanning the Cadaver

The specimen is placed in a supine position* on a CT scanner, (a Pfizer FS0200 Scanner was used for the purpose). Beginning at the cranium and ending at the ankle joints, scans are taken at one centimeter intervals. It takes approximately 30 seconds to complete a scan and to store the picture on a magnetic tape for permanent record. Once the specimen is positioned, the scanning and movement of the body to the next scanning position are automatically controlled by the scanner. The number of cross-sectional scans varies for each subject, depending on the height of the subject. Figure 1 shows eleven cross-sectional scan of a specimen through the upper thorax covering the complete left scapula.

3) Three-Dimensional Body and Anatomical Component Geometry

The three-dimensional body and anatomical component geometry of a specimen can now be obtained from the scans. Since the CT scans are already in a digital format, it is not necessary to digitalize the scan pictures. Because of the high density contrast between skeletal structures and the background, external body contours and boundaries of these structures can be obtained with a standard boundary detection computer program. Boundaries of organs and other anatomical features may require occasional manual editing due to the possible low density contrast among these structures. In these instances a computer program called THREAD[5] can be used. Figure 2 shows complete outlines

*Other scanning positions are also possible, for example prone, sitting, semi-prone and oblique. These scanning positions can be accomplished by first freezing the specimen at the desired position and then scanning it supinely.

of the left scapula extracted by the THREAD from scans shown in Figure 1. With either program, the outputs are the three-dimensional coordinates of all the boundary points of the body cross sections and the anatomical components of the specimen under consideration.

4) <u>Computing the Mass, Center of Gravity and Inertial Tensor for the Body Sections and Anatomical Components</u>

An experimental method converting a scan picture from relative X-ray absorption coefficients to mass density with a spatial resolution of 1.5mm x 1.5mm x thickness have been developed [6]. And the conversion is carried on for each pixel in the scan picture. The mass and inertial tensor of a cross section or an anatomical component can be obtained by standard formulas in mechanics.

IV. The Anatomical Cross-Sectional Geometry and Density Distribution Data Base Structure

At the present time, the following five types of information have been preserved for each specimen.

1) Scan picture of each cross section
2) Geometry of a body segment (or cross section)
3) Mass denstiy distribution of a body segment (or cross section)
4) Geometry of internal organs
5) Mass density distribution of internal organs

These five types of information on a specimen are all stored in a file. A file is a set of consecutive fixed length records of 512 bytes each. Each file is saved on a magnetic tape (or tapes) and will be read into a random access medium, for example, a disk for information retrieval. The content of each file is depicted in Figure 3.

User oriented computer programs are being developed to retrieve the following:

1) Geometry of a body segment of section

2) Mass density distribution of a body segment or section

3) Geometry of an internal organ

In addition, these programs will also be able to:

4) Save retrieved information for future study

5) Generate mesh of an internal organ from retrieved information for the Finted Elements Method.

V. Discussion

Precise and detailed three-dimensional geometry of the human body and density distribution of various tissues and skeletal structures is essential in many aspects of research related to biomechanics, such as, various simulation studies, and designing crash dummies. One large scale model now being used to study the extent of damage to vital anatomical components of the body is the Calspan 3-D Crash Simulation Program [7]. This program requires the mass, center of gravity and principle moments of inertia for each body segment as input data. Using the data base described makes the Calspan simulation program much easier to use, more realistic and lends greater meaning to its results. The data base so designed can be extended and enlarged without any changes in its structure to accomodate further specimens when desirable. An interpolation program is in the planning stage. This program will add geometric correction rules to modify a base internal (visceral) and external (body contour) geometry from the specimens already existing in the data base, so that newly derived geometry can be obtained. With such an addendum, the data base will be more flexible and the retrieval information more significant.

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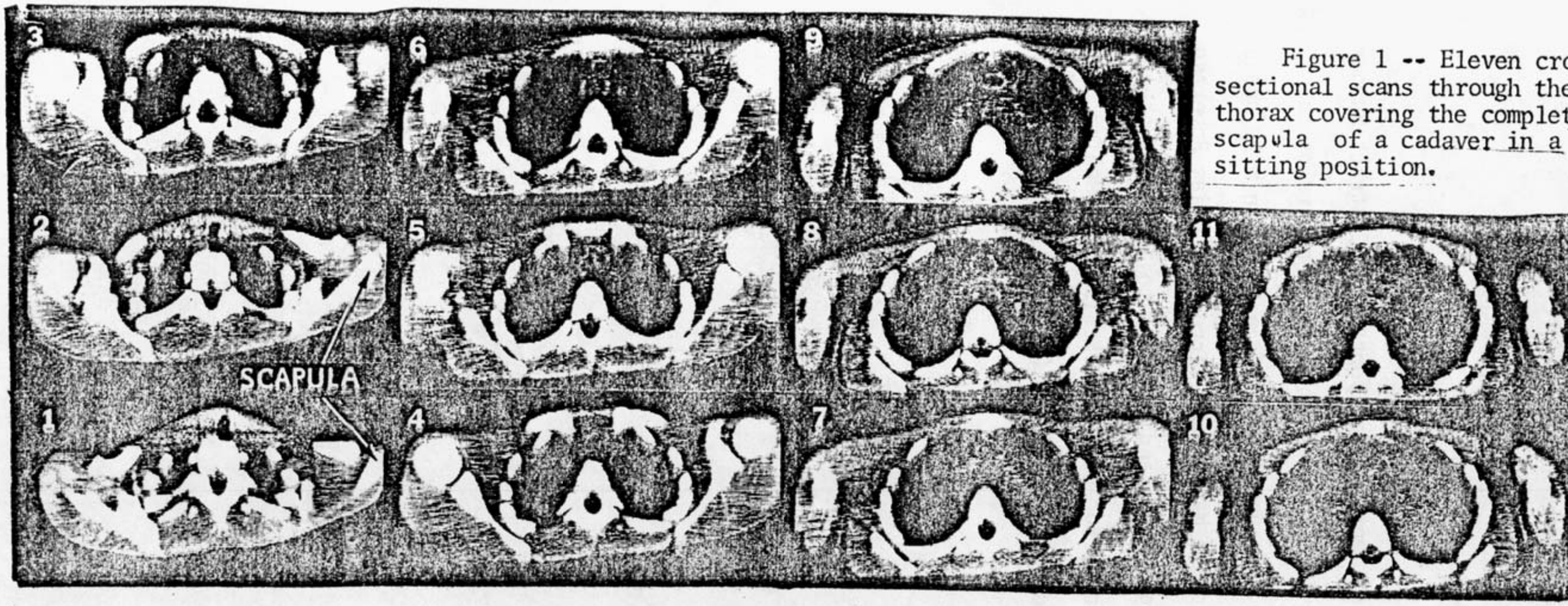

Figure 1 -- Eleven cross sectional scans through the upper thorax covering the complete left scapula of a cadaver in a sitting position.

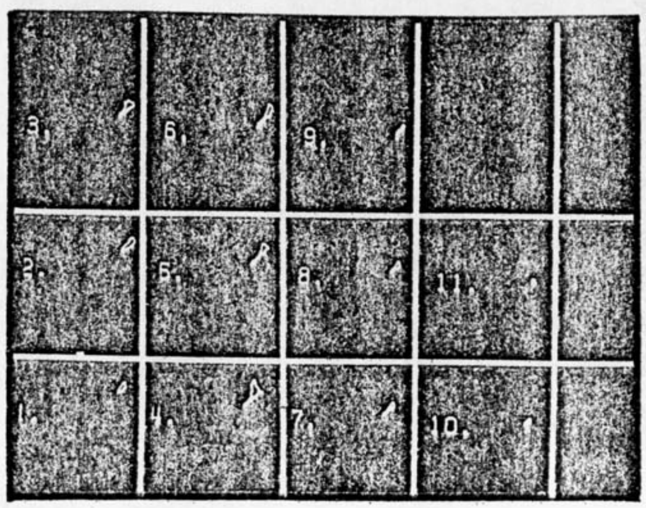

Figure 2 -- The complete outlines of the scapula as shown in Figure 1 obtained by the boundary detection method.

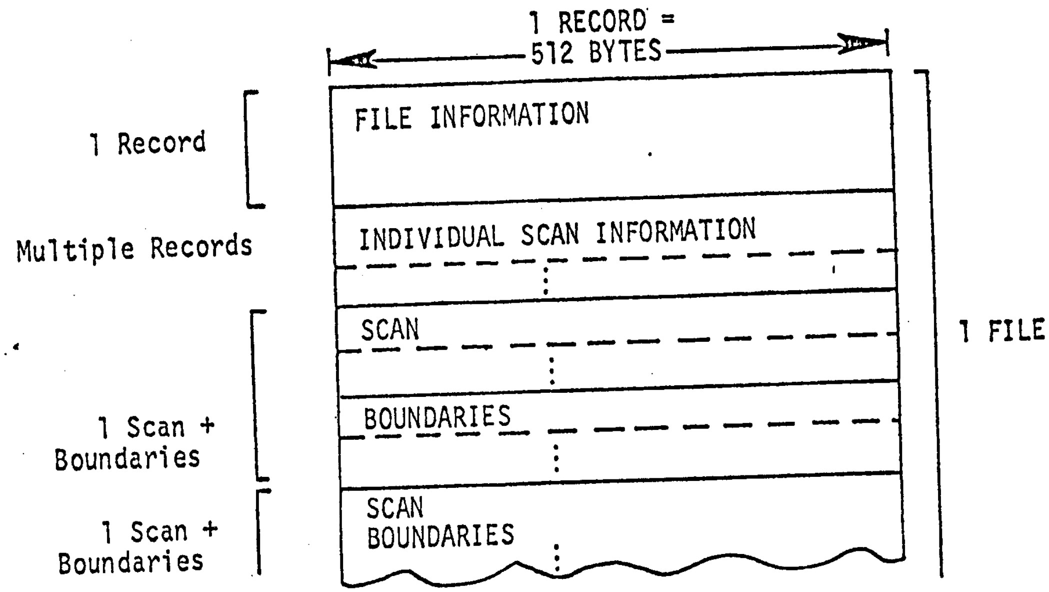

Figure 3 : The Overall Structrue of the Data Base

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